Section 4

Water in the Atmosphere

Objectives

After this lesson, students will be able to

I.2.4.1 Describe humidity and how it is measured.

I.2.4.2 Explain how clouds form.

I.2.4.3 Name the three main types of clouds.

Target Reading Skill

Asking Questions Explain that changing a head into a question helps students anticipate the ideas, facts, and events that they are about to read.

Answers

Possible questions and answers include the following:

How does the water cycle work? *(Water evaporates from the surface, condenses to form clouds, and falls to Earth as rain or snow.)* **What is relative humidity?** *(The percentage of water vapor in the air compared to the maximum amount air can hold at that temperature.)* **How do clouds form?** *(Water vapor in the air condenses to form liquid water or crystals.)* **Can you tell about weather conditions by looking at clouds?** *(Yes; each type of cloud is associated with a different type of weather.)*

All in One Teaching Resources

- Transparency I18

Preteach

Build Background Knowledge L1

Water Vapor

Ask: **When you take a shower, have you ever noticed that the bathroom mirror clouds up?** *(Yes.)* Explain that when warm, moist air from the shower comes into contact with the cool surface of the mirror, the air cools and can hold less water vapor. As a result, water vapor condenses on the mirror. Point out that clouds form in the same way: water vapor on particles in the atmosphere condenses when warm, moist air cools.

Section 4

Water in the Atmosphere

Reading Focus

Key Concepts

- What is humidity and how is it measured?
- How do clouds form?
- What are the three main types of clouds?

Key Terms

- water cycle
- evaporation
- humidity
- relative humidity
- psychrometer
- condensation
- dew point
- cirrus
- cumulus
- stratus

Target Reading Skill

Asking Questions Before you read, preview the red headings. In a graphic organizer like the one below, ask *what* or *how* questions for each heading. As you read, write answers to your questions.

The Water Cycle

Question	Answer
How does the water cycle work?	During the water cycle . . .

Lab zone Discover Activity

How Does Fog Form?

1. Fill a narrow-necked plastic bottle with hot tap water. Pour out most of the water, leaving about 3 cm at the bottom. **CAUTION:** *Avoid spilling hot water. Do not use water that is so hot that you cannot safely hold the bottle.*
2. Place an ice cube on the mouth of the bottle. What happens?
3. Repeat Steps 1 and 2 using cold water instead of hot water. What happens?

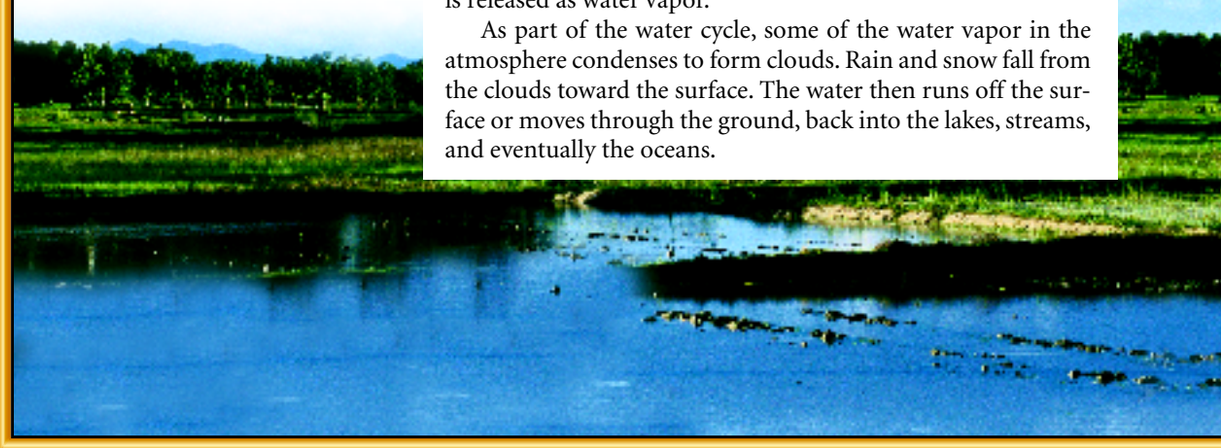
Think It Over

Developing Hypotheses How can you explain your observations? Why is there a difference between what happens with the hot water and what happens with the cold water?

During a rainstorm, the air feels moist. On a clear, cloudless day, the air may feel dry. As the sun heats the land and oceans, the amount of water in the atmosphere changes. Water is always moving between the atmosphere and Earth's surface.

The movement of water between the atmosphere and Earth's surface is called the **water cycle.** As you can see in Figure 13, water vapor enters the air by evaporation from the oceans and other bodies of water. **Evaporation** is the process by which water molecules in liquid water escape into the air as water vapor. Water vapor is also added to the air by living things. Water enters the roots of plants, rises to the leaves, and is released as water vapor.

As part of the water cycle, some of the water vapor in the atmosphere condenses to form clouds. Rain and snow fall from the clouds toward the surface. The water then runs off the surface or moves through the ground, back into the lakes, streams, and eventually the oceans.



Lab zone Discover Activity

Skills Focus Developing hypotheses L1

Materials narrow-necked plastic bottle, hot tap water, 2 ice cubes, cold tap water

Time 10 minutes

Tips Caution students to run hot water slowly out of the taps. Make sure that students let the bottle cool before repeating Steps 1 and 2 with cold water.

Expected Outcome Fog will form in the bottle when it contains hot water, but not when it contains cold water.

Think It Over Fog forms when warm, moist air rises from the surface of the hot water and condenses as it cools near the ice cube. This does not occur when the bottle contains cold water because cold water does not produce warm, moist air.

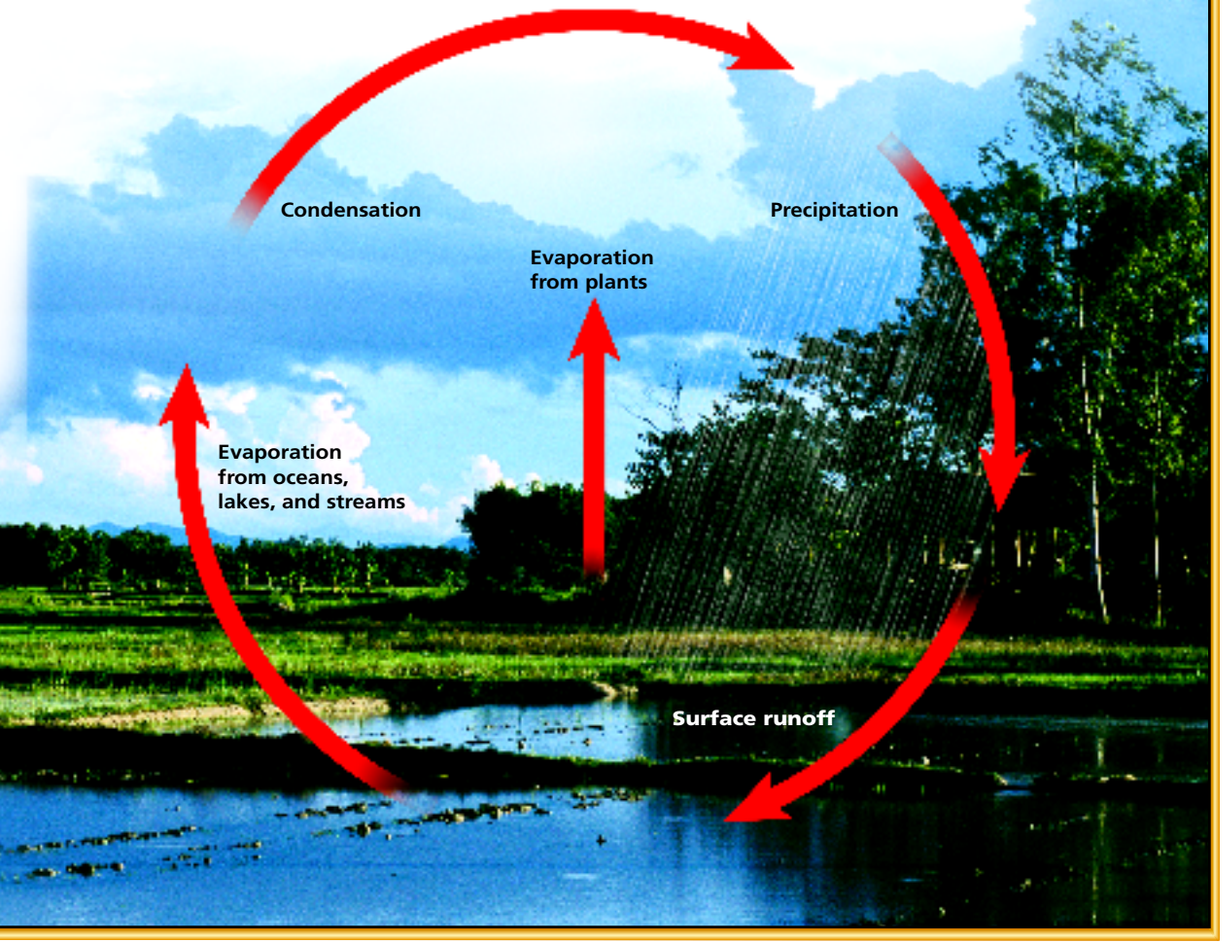
Humidity

How is the quantity of water vapor in the atmosphere measured? **Humidity** is a measure of the amount of water vapor in the air. Air's ability to hold water vapor depends on its temperature. Warm air can hold more water vapor than cool air.

Relative Humidity Weather reports usually refer to the water vapor in the air as relative humidity. **Relative humidity** is the percentage of water vapor that is actually in the air compared to the maximum amount of water vapor the air can hold at a particular temperature. For example, at 10°C, 1 cubic meter of air can hold at most 8 grams of water vapor. If there actually were 8 grams of water vapor in the air, then the relative humidity of the air would be 100 percent. Air with a relative humidity of 100 percent is said to be saturated. If the air had 4 grams of water vapor, the relative humidity would be half, or 50 percent.

FIGURE 13
Water Cycle
In the water cycle, water moves from oceans, lakes, rivers, and plants into the atmosphere and then falls back to Earth.

Go Online active art
For: Water Cycle activity
Visit: PHSchool.com
Web Code: cfp-4024



Differentiated Instruction

English Learners/Beginning L1
Comprehension: Modified Cloze
Write some simple sentences on the board that require the terms *evaporation, condensation, humidity, cumulus, stratus,* and *cirrus*. For example: "The amount of moisture in the air is its _____." Model how to do the first item. As students read through the section, have them fill in the blanks. **learning modality: verbal**

English Learners/Intermediate L2
Comprehension: Modified Cloze Use the same sentences described at left, but fill in incorrect terms. Have students work in pairs to determine the correct answers. **learning modality: verbal**

Instruct

Go Online active art
For: Water Cycle activity
Visit: PHSchool.com
Web Code: cfp-4024
Students can interact with the water cycle art online.

Humidity

Teach Key Concepts L1

Relative Humidity

Focus Show students a 5-gallon bucket. Tell them that it can hold 5 gallons of water. Ask: **If the bucket held 2.5 gallons, what percentage of the total amount that the bucket can hold would this be?** *(50%)* Tell students that relative humidity is calculated in a similar way.

Teach Ask: **If one cubic meter of air at 10°C can hold 8 grams of water vapor, what is the relative humidity if it contains 2 grams of water vapor?** *(25%)* Tell students that warmer air can hold more water vapor than colder air can. Ask: **How would the relative humidity change if the air temperature decreased?** *(It would go up.)* **Why?** *(The amount of water in the air would be a greater percentage of the amount that the colder air can hold.)*

Apply Ask: **Why might condensation occur if air cooled enough?** *(The amount of water in the air would become greater than the amount that the air could hold.)*

Independent Practice

All in One **Teaching Resources**
- Guided Reading and Study Worksheet: *Water in the Atmosphere*

Student Edition on Audio CD

Monitor Progress L2

Drawing Ask students to draw a diagram of the water cycle and label it with these terms: *evaporation, condensation,* and *precipitation*. Students can place their drawings in their portfolios. Portfolio

Lab zone Build Inquiry

L2

Measuring to Find the Dew Point

Materials beaker, water at room temperature, ice cubes, stirring rod, thermometer

Time 10 minutes

Focus Review the definition of dew point.

Teach Have students fill a beaker with cool tap water and record the temperature. Then have them add ice cubes to the beaker and stir. When moisture condenses on the outside of the beaker, have students record the temperature of the water again; this is the dew point in the classroom.

Apply Ask: **Would the dew point be the same if you performed this experiment on different days?** *(Probably not; the dew point depends on the temperature and relative humidity, which change from day to day.)* **learning modality: logical/mathematical**

Math Analyzing Data

Math Skill Interpreting Graphs

Focus Have a volunteer explain how to interpret the table. *(The boldface numbers represent the dry-bulb reading in degrees and the difference in degrees between the two bulbs. The other numbers represent the relative humidity.)*

Teach Tell students to subtract the wet-bulb reading from the dry-bulb reading and find the difference between the two readings in the table.

Answers

1. 64%
2. 88%
3. It decreased from 18 degrees to 12 degrees.
4. It increased.
5. For the same amount of water in the air, as the temperature decreases, the relative humidity increases. Warm air can hold more moisture than cool air can.

FIGURE 14
Sling Psychrometer
A sling psychrometer is used to measure relative humidity.

Measuring Relative Humidity

Relative humidity can be measured with an instrument called a psychrometer. A **psychrometer** (sy KRAHM uh tur) has two thermometers, a wet-bulb thermometer and a dry-bulb thermometer, as shown in Figure 14. The bulb of the wet-bulb thermometer has a cloth covering that is moistened with water. When the psychrometer is "slung", or spun by its handle, air blows over both thermometers. Because the wet-bulb thermometer is cooled by evaporation, its reading drops below that of the dry-bulb thermometer.

If the relative humidity is high, the water on the wet bulb evaporates slowly, and the wet-bulb temperature does not change much. If the relative humidity is low, the water on the wet bulb evaporates rapidly, and the wet-bulb temperature drops. The relative humidity can be found by comparing the temperatures of the wet-bulb and dry-bulb thermometers.

Reading Checkpoint **What instrument measures relative humidity?**

Math Analyzing Data

Determining Relative Humidity

Relative humidity is affected by temperature. Use the data table to answer the questions below. First, find the dry-bulb temperature in the left column of the table. Then find the difference between the wet- and dry-bulb temperatures across the top of the table. The number in the table where these two readings intersect indicates the relative humidity in percent.

Relative Humidity

Dry-Bulb Reading (°C)	Difference Between Wet- and Dry-Bulb Readings (°C)				
	1	2	3	4	5
10	88	76	65	54	43
12	88	78	67	57	48
14	89	79	69	60	50
16	90	80	71	62	54
18	91	81	72	64	56
20	91	82	74	66	58
22	92	83	75	68	60

1. **Interpreting Data** At noon, the readings on a sling psychrometer are 18°C for the dry-bulb thermometer and 14°C for the wet-bulb thermometer. What is the relative humidity?
2. **Interpreting Data** At 5 P.M., the psychrometer is used again. The reading on the dry-bulb thermometer is 12°C, and the reading on the wet-bulb thermometer is 11°C. Determine the new relative humidity.
3. **Interpreting Data** How did the temperature change between noon and 5 P.M.?
4. **Interpreting Data** How did relative humidity change during the course of the day?
5. **Drawing Conclusions** How was the relative humidity affected by air temperature? Explain your answer.

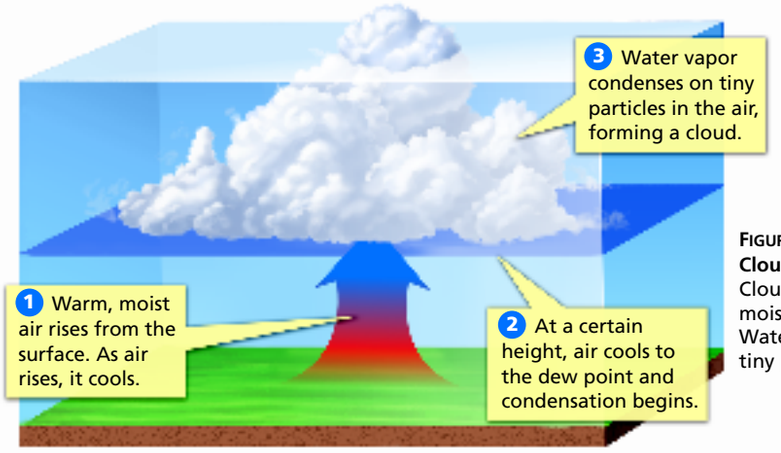


FIGURE 15
Cloud Formation
Clouds form when warm, moist air rises and cools. Water vapor condenses onto tiny particles in the air.

How Clouds Form

When you look at a cloud, you are seeing millions of tiny water droplets or ice crystals. **Clouds form when water vapor in the air condenses to form liquid water or ice crystals.** Molecules of water vapor in the air become liquid water in the process of **condensation.** How does water in the atmosphere condense? Two conditions are required for condensation: cooling of the air and the presence of particles in the air.

The Role of Cooling As you have learned, cold air holds less water vapor than warm air. As air cools, the amount of water vapor it can hold decreases. The water vapor condenses into tiny droplets of water or ice crystals.

The temperature at which condensation begins is called the **dew point.** If the dew point is above freezing, the water vapor forms water droplets. If the dew point is below freezing, the water vapor may change directly into ice crystals.

The Role of Particles But something else besides a change in temperature is needed for cloud formation. For water vapor to condense, tiny particles must be present so the water has a surface on which to condense. In cloud formation, most of these particles are salt crystals, dust from soil, and smoke. Water vapor also condenses onto solid surfaces, such as blades of grass or window panes. Liquid water that condenses from the air onto a cooler surface is called dew. Ice that has been deposited on a surface that is below freezing is called frost.

Reading Checkpoint **What two factors are required for condensation to occur?**

FIGURE 16
Condensation
Water vapor condensed on this insect to form dew. **Predicting** *What would happen if the surface were below freezing?*

How Clouds Form

Teach Key Concepts L2

Factors Causing Condensation

Focus Remind students that condensation is one part of the water cycle.

Teach Explain that as warm, moist air rises in the atmosphere, its temperature begins to decrease. The rising air becomes saturated and condenses, or reaches its dew point. Ask: **What happens at that point?** *(Clouds form.)* **What else is needed for cloud formation?** *(The water vapor must have a surface on which to condense.)*

Apply Ask students to explain why dew forms on plants in the early morning. *(Dew forms when the ground reaches the temperature at which water vapor condenses.)* **learning modality: logical/mathematical**

All in One Teaching Resources

- Transparency I19

Differentiated Instruction

Gifted and Talented L3

Graphing the Dew Point Have students listen to local weather reports or check the local newspaper to find the dew point and relative humidity for several days. Ask students to graph the relationships among the dew point, temperature, and relative humidity. **learning modality: logical/mathematical**

Less Proficient Readers L1

Understanding Concepts Select a passage from the text, such as The Role of Cooling or The Role of Particles. Read the passage aloud as students follow along in their books. After reading, ask some questions about the content of the passage. If students don't know the answers, challenge them to find them in the passage. **learning modality: verbal**

Monitor Progress L2

Writing Have students explain in their own words how temperature, humidity, and dew point are related.

Answers

Figure 16 Frost would form instead of dew.

Reading Checkpoint A psychrometer

Reading Checkpoint The cooling of air to the dewpoint or below and the presence of particles

Types of Clouds

Teach Key Concepts L2

Classifying Clouds

Focus Refer students to Figure 17.

Teach Give students a few moments to study the diagram, and then ask: **What do you notice about the relationship between altitude and types of clouds?** *(Different types of clouds form at different altitudes.)* Explain that cumulus clouds form during clear weather when warm air rises over small regions of Earth, such as parking lots, because these areas are heated more by the sun. Nimbostratus clouds are formed by warm air rising over a wide area, so they tend to cover the whole sky. Cumulonimbus clouds form when a great deal of hot air rises quickly and towers upward for several kilometers. Strong winds at the bottom of the stratosphere flatten the tops of cumulonimbus clouds to give them their characteristic anvil shape. Cirrus clouds are formed high in the atmosphere, where it is very cold and there is little water vapor, making these clouds thin and wispy.

Apply Ask: **What type of cloud might you see when a thunderstorm is approaching?** *(Cumulonimbus)* **What type of cloud are you likely to see on clear, cold days?** *(Cirrus)* **What type of weather can you expect when you see dark, flat clouds covering most of the sky?** *(Rain or snow)* **learning modality: visual**

All in One Teaching Resources

- Transparency I20

Cirrus clouds

Cumulus clouds

Stratus clouds

Types of Clouds

Clouds come in many different shapes, as shown in Figure 17. **Scientists classify clouds into three main types based on their shape: cirrus, cumulus, and stratus. Clouds are further classified by their altitude.** Each type of cloud is associated with a different type of weather.

Cirrus Clouds Wispy, feathery clouds are known as **cirrus** (SEER us) clouds. *Cirrus* comes from a word meaning a curl of hair. Cirrus clouds form only at high levels, above about 6 kilometers, where temperatures are very low. As a result, cirrus clouds are made of ice crystals.

Cirrus clouds that have feathery "hooked" ends are sometimes called mare's tails. Cirrocumulus clouds, which look like rows of cotton balls, often indicate that a storm is on its way. The rows of cirrocumulus clouds look like the scales of a fish. For this reason, the term "mackerel sky" is used to describe a sky full of cirrocumulus clouds.

Cumulus Clouds Clouds that look like fluffy, rounded piles of cotton are called **cumulus** (KYOO myuh lus) clouds. The word *cumulus* means "heap" or "mass" in Latin. Cumulus clouds form less than 2 kilometers above the ground, but they may grow in size and height until they extend upward as much as 18 kilometers. Cumulus clouds that are not very tall usually indicate fair weather. These clouds, which are common on sunny days, are called "fair weather cumulus." Towering clouds with flat tops, called cumulonimbus clouds, often produce thunderstorms. The suffix *-nimbus* means "rain."

Stratus Clouds Clouds that form in flat layers are called **stratus** (STRAT us) clouds. Recall that *strato* means "spread out." Stratus clouds usually cover all or most of the sky and are a uniform dull, gray color. As stratus clouds thicken, they may produce drizzle, rain, or snow. They are then called nimbostratus clouds.

Reading Checkpoint **What are stratus clouds?**

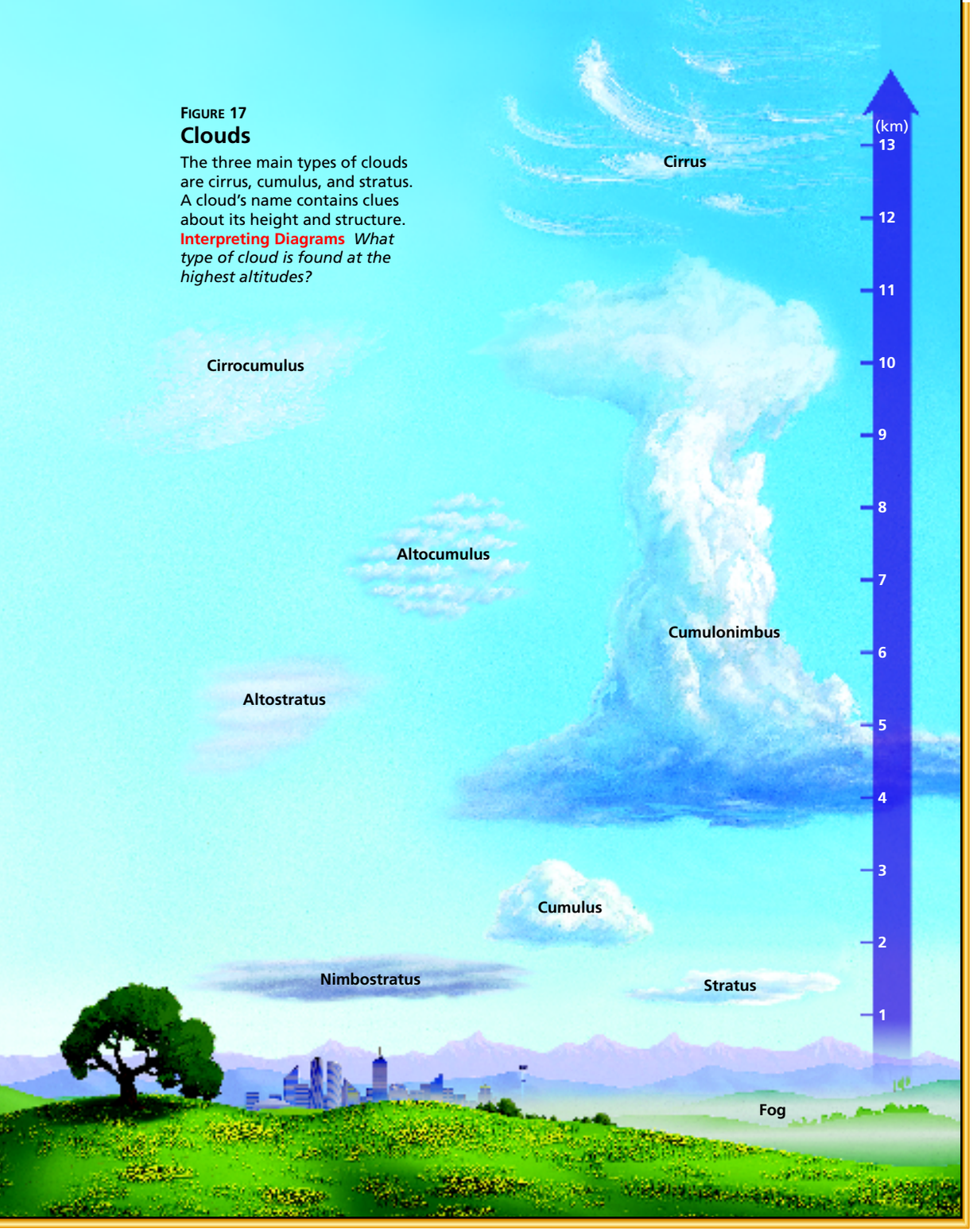


FIGURE 17
Clouds
The three main types of clouds are cirrus, cumulus, and stratus. A cloud's name contains clues about its height and structure.
Interpreting Diagrams *What type of cloud is found at the highest altitudes?*

Lab zone **Teacher Demo**

Observing How Clouds Form L2

Materials water, clean gallon bottle with cap, bicycle pump, nail

Time 10 minutes

Focus Review how clouds form by condensation.

Teach Explain that air gets warmer when it is compressed and cooler when it is allowed to expand. Cover the bottom of a gallon bottle with a few centimeters of water. Use a nail to punch holes in the cap until you have an opening about 0.5 cm in diameter. Place the cap on the bottle, and push the nozzle of a bicycle pump into the opening. Ask a volunteer to push down on the pump two or three times. Quickly release the cap, and a cloud will form inside the bottle.

Apply Ask: **Why did the cloud form inside the bottle?** *(Pumping air into the bottle compressed and warmed the air in the bottle, so it picked up moisture from the water. Releasing air from the bottle allowed the air in the bottle to expand and cool so that it could hold less water. Water condensed out of the air that remained in the bottle, forming a cloud.)* **learning modality: visual**

Differentiated Instruction

Special Needs L1
Recognizing Cloud Shapes Help students become more familiar with the distinctive shapes of the main cloud types. Display several drawings or pictures of the cloud types. Point out their distinctive shapes, and challenge students to identify them. **learning modality: visual**

Less Proficient Readers L1
Identifying Clouds Explain that the words *cumulus, stratus,* and *cirrus* describe basic cloud shapes. The word *nimbus* or the prefix *nimbo-* means that the cloud produces rain or snow. The prefix *alto-* means that the cloud is a medium-altitude cloud. The prefix *cirro-* means that the cloud is a high-altitude cloud. **learning modality: verbal**

Monitor Progress L2

Drawing Have students draw and label each of the three main cloud types. Have students save their drawings in their portfolios. Portfolio

Answers
Figure 17 cirrus
Reading Checkpoint Uniformly dull, gray clouds that form in flat layers

Monitor Progress L2

Answers

Figure 18 The heat of the sun will cause the water droplets in fog to evaporate.

Reading Checkpoint Clouds that form at or near the ground

Assess

Reviewing Key Concepts

1. a. A measure of the amount of water vapor in the air **b.** Humidity is the actual amount of water vapor in the air. Relative humidity is the percentage of water vapor actually in the air compared to the total amount of water vapor that the air can hold. **c.** 20%

2. a. Condensation **b.** Air must be cooled to its dew point, and particles must be present in the air. **c.** When the dew point is below freezing, ice crystals might form.

3. a. Cumulus, stratus, and cirrus **b.** Possible response: Cumulus clouds look like fluffy, rounded piles of cotton. Stratus clouds form in flat layers. Cirrus clouds are high, wispy, and feathery. **c.** Low-level clouds are fog, cumulus, stratus, and nimbostratus. Medium-level clouds are altocumulus and altostratus. High-level clouds are cirrostratus and cirrus.

Reteach L1

Have students look at the diagram of the water cycle and explain each of the steps in detail.

Performance Assessment L2

Have students infer why they can see their breath on a cold day. *(Water vapor from their warm, moist breath condenses when it enters the cold air.)*

All in One Teaching Resources

- Section Summary: *Water in the Atmosphere*
- Review and Reinforce: *Water in the Atmosphere*
- Enrich: *Water in the Atmosphere*

FIGURE 18
Fog Around the Golden Gate Bridge
The cold ocean water of San Francisco Bay is often covered by fog in the early morning.
Predicting *What will happen as the sun rises and warms the air?*

Altocumulus and Altostratus Part of a cloud's name may be based on its height. The names of clouds that form between 2 and 6 kilometers above Earth's surface have the prefix *alto-*, which means "high." The two main types of these clouds are altocumulus and altostratus. These are "middle-level" clouds that are higher than regular cumulus and stratus clouds, but lower than cirrus and other "high" clouds.

Fog Clouds that form at or near the ground are called fog. Fog often forms when the ground cools at night after a warm, humid day. The ground cools the air just above the ground to the air's dew point. The next day the heat of the morning sun "burns" the fog off as its water droplets evaporate. Fog is more common in areas near bodies of water or low-lying marshy areas. In mountainous areas, fog can form as warm, moist air moves up the mountain slopes and cools.

Reading Checkpoint **What is fog?**

Section 4 Assessment

Target Reading Skill

Asking Questions Use the answers to the questions you wrote about the headings to help answer the questions below.

Reviewing Key Concepts

1. a. Reviewing What is humidity?
b. Comparing and Contrasting How are humidity and relative humidity different?
c. Calculating Suppose a sample of air can at most hold 10 grams of water vapor. If the sample actually has 2 grams of water vapor, what is its relative humidity?

2. a. Identifying What process is involved in cloud formation?
b. Summarizing What two conditions are needed for clouds to form?
c. Inferring When are clouds formed by ice crystals instead of drops of liquid water?

3. a. Listing What are the three main types of clouds?
b. Describing Briefly describe each of the three main types of clouds.
c. Classifying Classify each of the following cloud types as low-level, medium-level, or high-level: altocumulus, altostratus, cirrostratus, cirrus, cumulus, fog, nimbostratus, and stratus.

Lab zone At-Home Activity

Water in the Air Fill a large glass half full with cold water. Show your family members what happens as you add ice cubes to the water. Explain to your family that the water that appears on the outside of the glass comes from water vapor in the atmosphere. Also explain why the water on the outside of the glass only appears after you add ice to the water in the glass.

Lab zone At-Home Activity

Water in the Air L1 Tell students to use cold tap water, not cold water from the refrigerator, which could cause the water to condense on the outside of the glass without the addition of ice. The water on the outside of the glass condenses from water vapor in the air. It appears only after ice is added because water vapor begins to condense out of the air when the temperature reaches the dew point.